

10 Rougheye Rockfish

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10.0 Executive Summary

We formalized the use of the generic rockfish model as the primary assessment tool for rougheye rockfish. The model was developed in a workshop held at the Auke Bay Laboratory in February 2001. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The data sets used include total catch biomass, fishery size compositions, trawl and longline survey biomass estimates and size compositions, and trawl survey age compositions. The projected ABC derived from the recommended model (Model 3) for 2006 is 983 mt which is about 2% lower than last year's ABC of 1,007 mt. The decrease in ABC is likely due to the decrease in the longline survey relative population weight in the 2005 survey. Recommended ABCs from area apportionments are 136 mt for the Western area, 608 mt for the Central area, and 239 for the Eastern area. Reference values for rougheye rockfish are summarized below. The stock is not overfished, nor is it approaching overfishing status.

	2006	2007*
$B_{40\%}$ (mt) (female spawning biomass)	8,399	-
Female Spawning Biomass (mt)	9,976	10,165
$F_{40\%}$	0.039	0.039
F_{ABC} (maximum permissible)	0.039	0.039
ABC (mt; maximum permissible)	983	990
F_{OFL}	0.047	0.047
OFL (mt)	1,180	1,188

*The 2007 ABC and OFL were projected using an expected catch value of 288 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author's F method was used for this projection (Table 10-9) in response to management requests for a more accurate one-year projection.

Summary of Major Changes to Model, Data, and Results

New data added to the model were the 2003 survey age composition, estimated 2005 fishery catch and size composition, estimated 2005 trawl and longline survey biomass estimates and size compositions. Consecutive trawl survey biomass estimates have remained relatively stable. New age agreement tests were conducted that allowed the development of an age error matrix based on rougheye rockfish specimens. Additionally, another method for determining the proportion of rougheye rockfish fishery catch in the shorttraker/rougheye complex from 1993-2004 was considered. We provide results from three separate age-structured models to analyze the effects of the new age error structure and catch data. Model 1 is the same as the author recommended model from Appendix B of last year's assessment with updated fishery and survey data. Model 2 uses the new age error structure. Model 3 uses the new age error structure and the new method for estimating catch data. Models using the new age error structure had relatively similar fits and parameter estimates (Models 2 and 3). We recommend the use of Model 3, which uses the new age error structure based on rougheye ages and the more accurate estimates of rougheye rockfish fishery catch.

Responses to SSC Comments

“The SSC encourages further development of this model, but estimates of recruitment, natural mortality and catchability parameters will be problematic until more data are available. The SSC concurs with the authors that an independent ageing error matrix be constructed instead of relying on the error structure borrowed from the POP assessment.”

We provide two age-structured models for rougheye rockfish that use the new age error matrix, and recommend the use of this matrix for future stock assessments. Additional age data was added this year and historic collections are currently being processed by the AFSC Age and Growth lab.

10.1 Introduction

10.1.1 Biology and Distribution

Rougheye rockfish (*Sebastes aleutianus*) inhabit the outer continental shelf and upper continental slope of the northeastern Pacific. Their distribution extends around the arc of the North Pacific from Japan to Point Conception, California and includes the Bering Sea (Kramer and O’Connell 1988). The center of abundance appears to be Alaskan waters, particularly the eastern Gulf of Alaska. In the Gulf of Alaska, as adults they inhabit a narrow band along the upper continental slope at depths of 300-500 m; outside of this depth interval, abundance decreases considerably (Ito, 1999). This species often co-occurs with shorttraker rockfish (*Sebastes borealis*) in trawl or longline hauls.

Little is known about the biology and life history of rougheye rockfish, but the fish appear to be long-lived, with late maturation and slow growth. As with other *Sebastes* species, rougheye rockfish are presumed to be viviparous, where fertilization and incubation of eggs is internal and embryos receive at least some maternal nourishment. There have been no studies on fecundity of rougheye in Alaska. One study on their reproductive biology indicated that rougheye had protracted reproductive periods, and that parturition (larval release) may take place in December through April (McDermott, 1994). The larval stage is pelagic, but larval studies are hindered because the larvae at present can only be positively identified by genetic analysis, which is both expensive and labor-intensive. The post-larvae and early young-of-the-year stages also appear to be pelagic (Matarese et al. 1989, Gharrett et al. 2002). Genetic techniques have been used recently to identify a few post-larval rougheye rockfish from samples collected in epibenthic waters far offshore in the Gulf of Alaska, which is the only documentation of habitat preference for this life stage.

There is no information on when juvenile fish become demersal. Juvenile rougheye rockfish (15- to 30-cm fork length) have been frequently taken in Gulf of Alaska bottom trawl surveys, implying the use of low relief, trawlable bottom substrates. They are generally found at shallower, more inshore areas than adults and have been taken in variety of locations, ranging from inshore fiords to offshore waters of the continental shelf. Studies using manned submersibles have found that large numbers of small, juvenile rockfish are frequently associated with rocky habitat on both the shallow and deep shelf of the GOA (Carlson and Straty 1981, Straty 1987, Krieger 1993). Another submersible study on the GOA shelf observed juvenile red rockfish closely associated with sponges that were growing on boulders (Freese and Wing 2004). Although these studies did not specifically identify rougheye rockfish, it is reasonable to suspect that juvenile rougheye rockfish may be among the species that utilize this habitat as refuge during their juvenile stage.

Adults are known to inhabit particularly steep, rocky areas of the continental slope, with highest catch rates generally at depths of 300 to 400 m in longline surveys (Zenger and Sigler 1992) and at depths of 300 to 500 m in bottom trawl surveys and in the commercial trawl fishery (Ito 1999). Observations from a manned submersible in this habitat indicate that the fish prefer steep slopes and are often associated with

boulders and sometimes with *Primnoa* spp. coral (Krieger and Ito 1999, Krieger and Wing 2002). Within this habitat, roughey rockfish tend to have a relatively even distribution when compared with the highly aggregated and patchy distribution of other rockfish such as Pacific ocean perch (*Sebastes alutus*).

Food habit studies in Alaska indicate that the diet of roughey rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are also consumed (Yang and Nelson 2000, Yang 2003). However, juvenile roughey rockfish (less than 30-cm fork length) in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Predators of roughey rockfish likely include halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be ruinous to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent work on black rockfish (*Sebastes melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and roughey rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for roughey rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age. The AFSC has funded a project to determine if this relationship occurs for similar slope rockfish in the Central Gulf of Alaska.

10.1.2 Evidence of stock structure

Genetic studies of roughey rockfish have indicated that this species shows stock structure in the Gulf of Alaska (Seeb 1986; Hawkins et al. 1997; Matala et al. 2003), but additional research is needed to better define this structure. Moreover, one recent study indicates that the genetic differences in stock structure of roughey rockfish are so large that the fish can be divided into two forms that are “clearly distinct species” (Gharrett et al. 2003). Each species form is loosely correlated with a light and dark color morph, and in some instances were found to co-occur in the same haul. A more comprehensive, recent study by Hawkins et al. (2005) determined that while both species were found in the Gulf of Alaska, the majority of the species found in the Central Gulf of Alaska were *Sebastes aleutianus* (the light-colored individuals), while those found in the Aleutian Islands were the species denoted *S. sp. cf. aleutianus* (typically the darker specimens) and typically distributed at deeper depths (330+ meters) than *S. aleutianus*. Species in Southeast Alaska were of both types. Research is in progress to determine if definitive morphological characteristics can be found to allow visual identification of the two species forms. Clearly, identification of two species of roughey rockfish could have important management implications in future assessments.

10.1.3 Management measures

In 1991, the North Pacific Fishery Management Council (NPFMC) divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/roughey rockfish, and all other species of slope rockfish. Although each management subgroup was assigned its own value of ABC (acceptable biological catch) and TAC (total allowable catch), shortraker/roughey rockfish and other slope rockfish were discussed in the same SAFE chapter because all species in these groups were

classified into tiers 4 or lower in the overfishing definitions. This resulted in an assessment approach based primarily on survey biomass estimates rather than age-structured modeling. In 1993, a fourth management subgroup, northern rockfish, was also created. In 2004, shortraker rockfish and rougheye rockfish were divided into separate subgroups. These subgroups were established to protect Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC and TAC, whereas prior to 1991, one ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on a weighted average of recent survey estimates of exploitable biomass distribution.

10.1.4 Fishery

Historical Background

Rougheye rockfish have been managed as “bycatch” only species since the creation of the shortraker/rougheye rockfish management subgroup in the Gulf of Alaska in 1991. Historically, Gulf-wide catches of the shortraker/rougheye subgroup have been consistently around 1,500-2,000 mt in the years since 1992. Annual TAC’s have been the major determining factor of these catch amounts, as TAC’s have also ranged between ~1,500-2,000 mt over these years. Rougheye are caught in either bottom trawls or with longline gear, and typically the majority of the catch has been taken by trawlers. Nearly all the longline catch of rougheye appears to come as “true” bycatch in the sablefish or halibut longline fisheries. However, in rockfish trawl fisheries some of the rougheye is taken by actual targeting that some fishermen call “topping off” (Ackley and Heifetz 2001). Fishery managers assign all vessels in a directed fishery a maximum retainable bycatch rate for certain species that may be encountered as bycatch. If a vessel manages to not catch this bycatch limit during the course of a directed fishing trip, or the bycatch rate is set unnaturally high (as data presented in Ackley and Heifetz (2001) suggest), before returning to port the vessel may be able to make some target hauls on the bycatch species and still not exceed its bycatch limit. Such instances of “topping off” for rougheye rockfish appear to take place in the Pacific ocean perch trawl fishery, especially because shortraker rockfish is the most valuable species of *Sebastes* in terms of landed price and rougheye often co-occur with shortraker in the trawl or longline hauls.

Bycatch

The only analysis of bycatch for rougheye rockfish is that of Ackley and Heifetz (2001) from 1994-1996 on hauls they identified as targeted on shortraker/rougheye rockfish. The major bycatch species were arrowtooth flounder (*Atheresthes stomias*), sablefish, and shortspine thornyhead (*Sebastolobus alascanus*), in descending order by percent.

Discards

Gulf-wide discard rates (percent of the total catch discarded within management categories) of fish in the shortraker/rougheye subgroup were available for the years 1991-2004, and are listed in the following table¹. Beginning in 2005, discards for rougheye rockfish should be reported separately.

Discards (%)	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2004</u>
Shortraker/ Rougheye	42.0	10.4	26.8	44.8	30.7	22.2	22.0	27.9	30.6	21.2	29.1	20.8	28.3	27.6

¹ National Marine Fisheries Service, Alaska Region, P.O. 21668, Juneau, AK 99802. Data are from weekly production and observer reports through October 14, 2005.

The above table indicates that discards of shortraker/rougheye have ranged from approximately 45% to 21% with an average of 27%. These values are relatively high when compared to other *Sebastes* species in the Gulf of Alaska.

10.2 Data

The following table summarizes the data available for this assessment:

Source	Data	Years
Fisheries	Catch	1977-2005
U.S. trawl fisheries	Length	1987-1988, 1990-1992, 2003-2005
Domestic trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
	Age	1990, 1999, 2003
	Length	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
Sablefish longline survey	Biomass index	1990-2005
	Length	1990-2005

10.2.1 Fishery Data

Catch

Catches of rougheye rockfish range from 130 mt to 2,418 mt from 1977 to 2005. The catches from 1977-1992 were from Soh (1998). Catches from 1993-2004 were available as the shortraker/rougheye subgroup from the NMFS Alaska Regional Office. Originally we used information from a document presented to the NPFMC in 2003 to determine the proportion of rougheye rockfish in this catch (Ianelli 2003). This proportion was based on the NMFS Regional Office catch accounting system (“blend estimates”). The SSC recommended using the average of the values provided in the document, 0.43. In 2004 another method was developed for determining the proportion of rougheye in the catch based on data from the NMFS Groundfish Observer Program (Clausen et al. 2004, Appendix A). Catches were available from the observer database by area, gear, and species for hauls sampled by observers. This information was used to calculate proportions of rougheye catch by gear type. These proportions were then applied to the combined shortraker/rougheye catch from the NMFS Alaska Regional Office to yield estimates of total catch for rougheye (Figure 10-1). We consider both of these methods for determining the proportion of rougheye rockfish in the catch and present separate model results for each catch series. These catches are presented in Table 10-1.

One caveat of the Observer data is that these data are based only on trips that had observers on board. Consequently, they may be biased toward larger vessels, which had more complete observer coverage. This bias may be a particular problem for rougheye that were caught by longliners. Much of the longline catch is taken by small vessels that have no observer coverage. Hence, the Observer data probably reflects more what the trawl fishery catches. However, this data may provide a more accurate estimate of the true proportion of rougheye catch than the proportion based on the blend estimates. The blend estimates are derived from a combination of data turned in by fishermen, processors, and observers. In the case of fishermen and processors, prior to 2004 there was no requirement to report catches of shortraker/rougheye rockfish by species, and fishermen and processors were free to report their catch as either shortraker, rougheye, or shortraker/rougheye combined. Shortraker and rougheye rockfish are often difficult for an untrained person to separate taxonomically, and fishermen and processors had no particular incentive to accurately identify the fish to species. In contrast, all observers in the NMFS Observer Program are trained in identification of Alaska groundfish, and they are instructed as to the importance of accurate identifications. Consequently, the catch data based on information from the Observer Program may be more reliable than those based on the blend estimate.

Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size composition of the commercial catch of rougheye rockfish. Table 10-2 summarizes the available length compositions from 1987-2004. There were no data available for 1989, 1993-2002. Lengths were binned into 2 cm categories to obtain better sample sizes per bin from 20-60+ with the (+) group containing all the fish 60 cm and larger. Approximately 80% of the lengths are from the trawl fishery and 20% are from the longline fishery.

10.2.2 Survey Data

10.2.2.1 Bottom Trawl Survey

Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999. These surveys became biennial starting in 2001. The surveys provide much information on rougheye rockfish, including an abundance index, age composition, and growth characteristics. The surveys are theoretically an estimate of absolute biomass, but we treat them as an index in the stock assessment model. The triennial surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 1,000 m), but the 2001 biennial survey did not sample the eastern Gulf of Alaska. We use data from the triennial surveys and the 2003 and 2005 biennial survey.

Summaries of biomass estimates from the 1984-2003 surveys are provided in Table 10-3. Trawl survey biomass estimates are shown in Figure 10-2. Since the 2001 survey did not sample the Eastern Gulf and we had an index for that year from the longline survey, we did not use it in this model.

The 1984 and 1987 survey results should be treated with some caution. A different survey design was used in the eastern Gulf of Alaska in 1984; furthermore, much of the survey effort in the western and central Gulf of Alaska in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this latter problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates discussed here, and the estimates are believed to be the best available. Even so, the reader should be aware that an element of uncertainty exists as to the standardization of the 1984 and 1987 surveys.

The biomass estimates for rougheye have been relatively constant among the surveys (with the possible exception of 1993), and the overlapping confidence intervals for this species in all the surveys (Table 10-3; Figure 10-2) indicate that none of the changes in biomass are statistically significant. Compared with other species of *Sebastes*, the biomass estimates for rougheye rockfish show relatively tight confidence intervals and low coefficients of variations (CV), ranging between 11% and 23%. The low CVs are an indication of the rather uniform distribution for this species compared with other slope rockfish such as northern rockfish (Section 10.1.1). Despite this precision, however, the trawl surveys are believed to do a relatively poor job of assessing abundance of rougheye rockfish. Nearly all the catch of these fish is found on the upper continental slope at depths of 300-500 m. Much of this area is not trawlable by the survey's gear because of its steep and rocky bottom, except for gully entrances where the bottom is not so steep. If rougheye rockfish are located disproportionately on rough, untrawlable bottom, then the trawl survey may underestimate their abundance. Conversely, if the bulk of their biomass is on smoother, trawlable bottom, then we could be overestimating their abundance with the trawl survey estimates. Consequently, trawl survey biomass estimates for rougheye rockfish are mostly based on the relatively few hauls in gully entrances, and they may not indicate a true picture of the abundance trends. However, the utilization of

both the trawl and longline (which can sample where survey trawls cannot) biomass estimates should alleviate some of this concern.

Age Compositions

Age determination for rougheye rockfish is problematic. This species appear to be among the longest-lived of all rockfish species, and interpretation of annuli on otoliths is extremely difficult. However, recently NMFS age readers determined that aging of rougheye rockfish could be moved into a production mode. Ages were determined from the break-and-burn method (Chilton and Beamish 1982). Another age composition (2003) was added this year. We now have three years of survey age compositions, 1990, 1999, and 2003, with sample size total of 1,376 ages. Although rougheye rockfish have been reported to be greater than 200 years old (Munk 2001), the highest age collected in these three years was 129. The average age was 18.5, 17.1, and 18.1 years in 1990, 1999, and 2003, respectively (Table 10-4). The 1990 age data show especially prominent modes at ages 9-11, 14 (corresponding to the 1979-1981 and 1976 year classes, respectively), and the (+) group. Another prominent mode appears in the 1999 data at age 9 and to a lesser degree at age 5. A broad peak occurs in the older fish (ages 16-18) in the 1999 data, possibly indicating a high survival proportion from the younger fish in 1990. The new age data for 2003 did show a large proportion of older fish in the (+) group and smaller spikes in the younger fish (3, 5, 8-9). There is a small spike of age 12-14 fish possibly corresponding to the age 9 fish that survived from 1999. Ages used in the model were from 3-25+ with older ages pooled into the (+) group.

Survey Size Compositions

Gulf-wide population size compositions for rougheye rockfish are in Table 10-5. The size compositions of rougheye rockfish in surveys from 1993 to present indicated that a sizeable portion of the population each year was <30 cm in length. This suggests that at least a moderate level of recruitment has been occurring throughout these years or there are fewer larger fish in the population. Compositions from all surveys (with the possible exception of 1990) were all skewed to the right, with a mode of about 43-45 cm. The 1990, 1999, and 2003 size compositions were not explicitly used in the model because survey ages for these years were available. The 1990 and 1999 size information is incorporated into the size-age matrix.

10.2.2.2 Sablefish Longline Survey

Biomass Estimates from Longline Surveys

Catch, effort, and length data were collected during sablefish longline surveys for rougheye rockfish. Rougheye data were collected outside of the SR/RE complex since 1990. These longline surveys likely provide an accurate index of sablefish abundance (Sigler 2000) and may also provide a reasonable index for rougheye rockfish in addition to the trawl surveys.

Longline data were expressed as a relative population weight (RPW) and used as a second biomass index in the model. The standard deviation of the time series was used as the standard error of the individual estimates and equaled approximately 20%. The index along with confidence intervals is provided in Table 10-6 and shown in Figure 10-3. Longline survey RPW estimates for rougheye have been relatively constant since 1990, with the exception of large increases in 1997 and 2000, and the sharp decline in 2005. Confidence intervals overlap in all surveys indicating that none of the changes in RPW are statistically significant.

As mentioned in the previous section, the trawl survey is not typically capable of sampling the deeper depths and high relief habitat of rougheye rockfish. This is not the case with the longline survey which can sample a large variety of habitats. One drawback, however, is that juvenile fish are not susceptible to longline gear. Subsequently, the longline survey does not provide much information on recruitment. The trawl survey may be limited in sampling particular habitats, but does capture juveniles. Another potential

concern is the unknown effect due to competition between larger predators for hooks. Incorporating both longline and trawl survey estimates in the model should remedy some of these issues.

Survey Size Compositions

Large samples of length compositions were collected Gulf-wide for a subsample of rougheye rockfish. These compositions show that small fish were rarely caught in the longline survey and that the length distribution was fairly stable through time (Table 10-7).

10.3 Analytic Approach

10.3.1 Model Structure

We present model results for rougheye rockfish based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). Previously, the rougheye rockfish stock assessment was based solely on trawl survey biomass estimates. The assessment model is now based on a generic rockfish model developed in a workshop held in February 2001² and follows closely the GOA Pacific ocean perch model which follows the northern rockfish model (Courtney et al 1999; Hanselman et al. 2003). As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there is no information on low spawners and low recruits (Figure 10-4). The main difference between the rougheye model and the Pacific ocean perch model is the addition of data from the sablefish longline survey. Unlike the Pacific ocean perch model, the starting point for the rougheye model was 1977, so the population at the starting point has already sustained significant fishing pressure. The parameters, population dynamics and equations of the model are described in Box 1.

10.3.2 Parameters Estimated Independently

Size at 50% maturity has been determined for 430 specimens of rougheye rockfish (McDermott 1994). This was converted to 50% maturity-at-age using the size-at-age matrix from this stock assessment. These data are summarized below (size is in cm fork length and age is in years).

<u>Sample size</u>	<u>Size at 50% maturity (cm)</u>	<u>Age at 50% maturity</u>
430	43.9	19

A von Bertalanffy growth curve was fitted to survey size-at-age data from 1990 and 1999. Sexes were combined. A size-at-age transition matrix was then constructed by adding normal error with a standard deviation equal to the standard deviation of survey ages for each size class. The estimated parameters for the growth curve are shown below:

$$L_{\infty}=51.2 \text{ cm} \quad \kappa=0.08 \quad t_0=-1.15 \quad n=866$$

Weight-at-age was constructed with weight-at-age data from the same data set as the length-at-age. The estimated growth parameters are shown below. A correction of $(W_{\infty}-W_{25})/2$ was used for the weight of the pooled ages (Schnute et al. 2001).

$$W_{\infty}=2311 \text{ g} \quad \kappa=0.05 \quad t_0=1.68 \quad \beta=1.712 \quad n=735$$

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age. Originally we used the error structure of the Pacific ocean perch model because we used approximately the same age bins for the rougheye assessment. New age

² Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

agreement tests were run on all the rougheye age samples that have been released since 1990, which were 2409 specimens and 1044 tests. We then estimated a new age error structure based on the percent agreement for each age from these tests. Model results are presented using both age error matrices.

10.3.3 Parameters estimated conditionally

Parameters estimated conditionally include but are not limited to: catchability, selectivity (up to full selectivity) for surveys and fishery, recruitment deviations, mean recruitment, fishing mortality, natural mortality, and spawners per recruit levels. Other parameters are described in Box 1.

10.3.4 Uncertainty

Evaluation of model uncertainty has recently become an integral part of the “precautionary approach” in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the models presented in this SAFE report, the number of parameters estimated is 127. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The “burn-in” is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 50,000 iterations out of 5,000,000 and “thinned” the chain to one value out of every thousand, leaving a sample distribution of 4,950. We compared running means of the chain, examined autocorrelation, and examined traces of the chains after removing the “burn-in” and “thinning”. We believe that convergence to the posterior distribution was likely if a long chain was used and obvious problems in diagnostic plots were not encountered. We used these MCMC methods to provide further evaluation of uncertainty in the results below.

BOX 1. AD Model Builder Rougheye Model DescriptionParameter
definitions

y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age at first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
ϕ_y	Annual fishing mortality deviation
τ_y	Annual recruitment deviation
σ_r	Recruitment standard deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, log-scale estimation
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\epsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\epsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q_1	Trawl survey catchability coefficient
q_2	Longline survey catchability coefficient
SB_y	Spawning biomass in year y , ($=m_a w_a N_{y,a}$)
M_{prior}	Prior mean for natural mortality
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment variance
σ_M^2	Prior CV for natural mortality
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * (1 - e^{-Z_{y,a}})}{Z_{y,a}} * w_a$$

Catch equation

$$\hat{I}_{1y} = q_1 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$$

Trawl survey biomass index (mt)

$$\hat{I}_{2y} = q_2 * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$$

Longline survey biomass index (mt)

$$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$$

Survey age distribution
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$$

Survey length distribution
Proportion at length

$$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$$

Fishery age composition
Proportion at age

$$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$$

Fishery length composition
Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{(\mu_r + \tau_{\text{styr}-a_0-a-1})}, & a = a_0 \\ e^{(\mu_r + \tau_{\text{styr}-a_0-a-1})} e^{-(a-a_0)M}, & a_0 < a < a_+ \\ \frac{e^{(\mu_r)} e^{-(a-a_0)M}}{(1 - e^{-M})}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{(\mu_r + \tau_y)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Formulae for likelihood components

$$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$$

$$L_2 = \lambda_2 \sum_y \frac{(I_{1y} - \hat{I}_{1y})^2}{2 * \hat{\sigma}^2(I_{1y})}$$

$$L_3 = \lambda_3 \sum_y \frac{(I_{2y} - \hat{I}_{2y})^2}{2 * \hat{\sigma}^2(I_{2y})}$$

$$L_4 = \lambda_4 \sum_{styr}^{endyr} -n_y \sum_l^{l+} (P_{y,l} + 0.001) * \ln(\hat{P}_{y,l} + 0.001)$$

$$L_5 = \lambda_5 \sum_{styr}^{endyr} -n_y \sum_a^{a+} (P_{y,a} + 0.001) * \ln(\hat{P}_{y,a} + 0.001)$$

$$L_6 = \lambda_6 \sum_{styr}^{endyr} -n_y \sum_l^{l+} (P_{y,l} + 0.001) * \ln(\hat{P}_{y,l} + 0.001)$$

$$L_7 = \lambda_7 \sum_{styr}^{endyr} -n_y \sum_l^{l+} (P_{y,l} + 0.001) * \ln(\hat{P}_{y,l} + 0.001)$$

$$L_8 = \frac{1}{2\sigma_M^2} \left(\ln M / M_{prior} \right)^2$$

$$L_9 = \frac{1}{2\sigma_{q_1}^2} \left(\ln q_1 / q_{1prior} \right)^2$$

$$L_{10} = \frac{1}{2\sigma_{q_2}^2} \left(\ln q_2 / q_{2prior} \right)^2$$

$$L_{11} = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \sigma_r / \sigma_{r(prior)} \right)^2$$

$$L_{12} = \lambda_{12} \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln(\sigma_r) \right]$$

$$L_{13} = \lambda_{13} \sum_y \varepsilon_y^2$$

$$L_{14} = \lambda_{14} \bar{s}^2$$

$$L_{15} = \lambda_{15} \sum_{a_0}^{a_+} (s_i - s_{i+1})^2$$

$$L_{16} = \lambda_{16} \sum_{a_0}^{a_+} (FD(FD(s_i - s_{i+1})))^2$$

$$L_{total} = \sum_{i=1}^{16} L_i$$

BOX 1 (Continued)

Catch likelihood

Trawl survey biomass index likelihood

Longline survey biomass index likelihood

Fishery length composition likelihood

Trawl survey age composition likelihood

Trawl survey size composition likelihood

Longline survey size composition likelihood

Penalty on deviation from prior distribution of natural mortality

Penalty on deviation from prior distribution of catchability coefficient for trawl survey

Penalty on deviation from prior distribution of catchability coefficient for longline survey

Penalty on deviation from prior distribution of recruitment deviations

Penalty on recruitment deviations

Fishing mortality regularity penalty

Average selectivity penalty (attempts to keep average selectivity near 1)

Selectivity dome-shapedness penalty – only penalizes when the next age's selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)

Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)

Total objective function value

10.4 Model Evaluation

10.4.1 Alternative Models

We consider three different models in this SAFE, the details of which are described below. The models explore the addition of information regarding the SSC comments on age error structure and the different proportions of rougheye rockfish catch in the shortraker/rougheye complex. We recommend the use of Model 3 for determining ABC. This model uses an age error matrix based on rougheye rockfish ages and more accurate estimates of rougheye rockfish fishery catch.

10.4.1.1 Model 1: Original model from 2004

This model was the author recommended model presented in Appendix B of the 2004 GOA Shortraker/Rougheye and Other Slope Rockfish assessment (Clausen et al. 2004). This model was not used to determine 2005 ABC, and was included as an alternative methodology to the Tier 5 approach. It is similar to the GOA Pacific ocean perch model with the additional estimation of catchability and selectivity for the longline survey. All data components were given a likelihood weighting of one. Age and length data was weighted inside the multinomial likelihoods by sample size scaled to a maximum of 100. We used informative priors on trawl survey catchability, natural mortality, and recruitment variation. We used a noninformative prior for the longline survey catchability, since we did not know a realistic range of values.

10.4.1.2 Model 2: New age error structure

Model 2 is identical to Model 1, with the exception that we use the new age error matrix developed from the new age agreement tests for all rougheye rockfish aged specimens since 1990.

10.4.1.3 Model 3: New age error structure, catch proportion based on observer data

Model 3 is identical to Model 2, but we incorporate the yearly proportions of rougheye rockfish in the shortraker/rougheye complex based on the observer data instead of the blend estimates. This applies to catch data from 1993-2004.

10.5 Model Results

10.5.1 Model Comparison

Table 10-8 summarizes the results from the three alternative models. Models 2 and 3 have similar fits to the data, while Model 1 has a slightly worse fit. The difference between the model fits is most obvious in the survey age composition likelihood, which supports the use of the more appropriate age error matrix based on rougheye rockfish data. In general, other results from the three models were very similar; therefore, we only provide graphs for the recommended model. Model fits to fishery size compositions were nearly identical (Figure 10-5). Fits to the survey age compositions (Figure 10-6) were slightly worse for Model 1 in 1999 and 2003 than the other two models. The fits to the trawl survey biomasses were reasonable for all three models (Figure 10-2) as were fits to size compositions (Figure 10-7). Fits to longline survey relative population weights were slightly better for Model 1 than Models 2 and 3 (Figure 10-3), while fits to the longline survey size compositions were nearly identical for all three models (Figure 10-8). Trawl survey biomass estimates from all three models did not capture the observed increased biomass in 1993. The large catches between 1988 and 1990 (Figure 10-1) and the associated high estimates of fishing mortality (Figure 10-9) may have driven down future population estimates for a time. Also, the 1993 predicted trawl survey length compositions for all three models disagreed to some extent with the observed values (Figures 10-7). In contrast, the longline survey biomass estimates (Figure 10-3) do increase slightly between the observed increases in 1997 and 2000, particularly in Model 1. This

reaction of the model was likely due to the consecutive longline surveys and the better agreement between predicted and observed length compositions for those years. Average observed biomass years in 1996, 1998, 1999, and 2001 surrounded the spikes of 1997 and 2000, which would restrict the model from large increases in predictions of longline survey biomass estimates.

Biomass estimates were very similar in all three models and suggested that the time series was stable or slightly increasing in the most recent years (Figure 10-10, 11). Results of MCMC simulation show fairly wide confidence bands for biomass estimates; however, the confidence bands for all three models are tighter than the models presented in Appendix B of the 2004 GOA Shortraker/Rougheye and Other Slope Rockfish assessment (Clausen et al. 2004). Fishing mortality was fairly consistent between the models (Figure 10-9), with perhaps the exception of Model 3 with a slightly larger decrease in fishing mortality in the most recent years. This is likely due to the decreased proportion of rougheye rockfish in the catch based on the observer estimates versus the blend estimates (Table 10-1). Estimated selectivity curves were similar to what was expected (Figure 10-12). The commercial fishery should target larger and subsequently older fish and the trawl survey should sample a larger range of ages. The longline survey samples deeper depths and small fish are not susceptible to the gear. The fishery selectivity curve should fall somewhere between the longline and trawl selectivity curves.

MCMC confidence bands for recruitment nearly contain zero for most recruitment estimates, indicating these estimates were a source of considerable uncertainty in the model (Figure 10-13). However, fewer confidence bands contained zero for Model 3 and were, in general, not as variable as the other two models. Recruitment also seems to be fairly stable throughout the time series for all models (Figure 10-13), except for the most recent years, where typically very little information is known about the population. There also does not seem to be a clear spawner-recruit relationship for rougheye rockfish as recruitment is apparently unrelated to spawning stock biomass and there is little contrast in spawning stock biomass (Figure 10-4). Models 2 and 3 also estimate a smaller recruitment in 1984 than Model 1, which likely reflects the higher age error for older rougheye rockfish than was previously estimated using the Pacific ocean perch age error structure.

Goodman et al. (2002) suggested that stock assessment authors use a “management path” graph as a way to evaluate management and assessment performance over time. In a management path we plot estimated fishing mortality relative to the (current) target value and the estimated spawning biomass relative to the (current) target spawning biomass. The management paths from all three models suggest that management is on track and has kept the stock in the ‘optimum’ quadrant where $B_{\text{now}}/B_{40\%}$ exceeds one and $F_{\text{now}}/F_{40\%}$ continues to stay below one (Figure 10-14). The scenario for all three models was very similar and suggested that fishing mortality exceeded $F_{40\%}$ several times since 1977.

10.6 Projections and Harvest Alternatives

10.6.1 Amendment 56 Reference Points

Amendment 56 to the GOA Groundfish Fishery Management Plan defines the “overfishing level” (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, rougheye rockfish in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces

the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2002 (year classes between 1977 and 1999). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. The 2005 estimates of these reference points are in the following table. Biomass estimates are for female spawning biomass.

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
20,997 (mt)	8,399 (mt)	7,349 (mt)	0.039	0.047

10.6.2 Specification of OFL and Maximum Permissible ABC

Female spawning biomass for 2006 is estimated at 9,976 mt. This is above the $B_{40\%}$ value of 8,399 mt. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2006, yields the following ABC and OFL:

$F_{40\%}$	0.039
ABC (mt)	983
$F_{35\%}$	0.047
OFL (mt)	1,180

10.6.3 Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3. This set of projections that encompasses seven harvest scenarios is designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2005 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2005. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. For the first three years, an estimated catch is used that is equal to the current ratio of catch to TAC. In subsequent years, total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2006, are as follows (“ $\max F_{ABC}$ ” refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to $\max F_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of $\max F_{ABC}$, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the $\max F_{ABC}$ for 2006. (Rationale: When F_{ABC} is set at a value below $\max F_{ABC}$, it is often set at the value recommended in the stock assessment.) In this scenario we use pre-specified catch for 2006 to provide a more accurate short-term projection of spawning biomass and ABC for species such as rougheye where much of the ABC goes unharvested.

Scenario 3: In all future years, F is set equal to 50% of $\max F_{ABC}$. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2001-2005 average F . (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC} .)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL} . (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2006 or 2) above $\frac{1}{2}$ of its MSY level in 2006 and above its MSY level in 2016 under this scenario, then the stock is not overfished.)

Scenario 7: In 2006 and 2007, F is set equal to $\max F_{ABC}$, and in all subsequent years, F is set equal to F_{OFL} . (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2018 under this scenario, then the stock is not approaching an overfished condition.)

10.6.4 Status Determination

Harvest scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest scenarios #6 and #7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2006:

- a) If spawning biomass for 2006 is estimated to be below $\frac{1}{2} B_{35\%}$, the stock is below its MSST.
- b) If spawning biomass for 2006 is estimated to be above $B_{35\%}$, the stock is above its MSST.
- c) If spawning biomass for 2006 is estimated to be above $\frac{1}{2} B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest scenario #6 (Table 10-9). If the mean spawning biomass for 2016 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest scenario #7 (Table 10-9):

- a) If the mean spawning biomass for 2006 is below $\frac{1}{2} B_{35\%}$, the stock is approaching an overfished condition.

- b) If the mean spawning biomass for 2006 is above $B_{35\%}$, the stock is not approaching an overfished condition.
- c) If the mean spawning biomass for 2006 is above $\frac{1}{2} B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2018. If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

A summary of the results of these scenarios for rougheye rockfish is in Table 10-9. For rougheye rockfish the stock is not overfished and is not approaching an overfished condition.

10.6.5 Area Allocation of Harvests

Prior to the 1996 fishery, the apportionment of ABC among areas was determined from distribution of biomass based on the average proportion of exploitable biomass by area in the most recent three triennial trawl surveys. As in the past, exploitable biomass for rougheye rockfish was estimated by the unweighted average biomass of the most recent three trawl surveys (2001, 2003, and 2005), excluding the estimated biomass in the 1-100 m depth stratum. The 1-100 m depth stratum was removed from the estimate because most rockfish in this stratum are small juvenile fish younger than the age of recruitment, and thus are not considered exploitable. For the 1996 fishery, an alternative method of apportionment was recommended by the Plan Team and accepted by the Council. Recognizing the uncertainty in estimation of biomass yet wanting to adapt to current information, the Plan Team chose to employ a method of weighting prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3 the weight of the preceding survey. These results in weights of 4:6:9 for the 2001, 2003, and 2005 surveys, respectively and apportionments for rougheye rockfish of 14% for the Western area, 62% for the Central area, and 24% for the Eastern area (Table 10-10). Applying these percentages to the ABC for rougheye rockfish (983 mt) yields the following apportionments for Gulf of Alaska 2006: 136 mt for the Western area, 608 mt for the Central area, and 239 mt for the Eastern area.

10.6.6 Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $FOFL = F_{35\%} = 0.047$), overfishing is set equal to 1,180 mt for rougheye rockfish.

10.7 Ecosystem Considerations

In general, a determination of ecosystem considerations for rougheye rockfish is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 10-11. Additionally, we include a summary of nontarget species bycatch estimates and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 1997-2005 (Table 10-12).

10.7.1 Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of rougheye rockfish appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval rougheye rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval rougheye rockfish (Gharrett et. al 2001). Food habit studies in Alaska indicate that the diet of rougheye rockfish is primarily shrimp (especially pandalids) and that various fish species such as myctophids are

also consumed (Yang and Nelson 2000, Yang 2003). Juvenile rougheye rockfish in the GOA also consume a substantial amount of smaller invertebrates such as amphipods, mysids, and isopods (Yang and Nelson 2000). Little if anything is known about abundance trends of likely rockfish prey items.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages and to some extent marine mammals during late juvenile and adult stages. Likely predators of rougheye rockfish likely include halibut, Pacific cod, and sablefish. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile rockfish, but information on these life stages and their predators is unknown.

Changes in physical environment: Strong year classes corresponding to the period around 1976-77 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including rougheye rockfish. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have effect on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in early juvenile stage have been found in floating kelp patches which would be subject to ocean currents. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions.

10.7.2 Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for rougheye rockfish account for very little bycatch of HAPC biota. This low bycatch may be explained by the fact that little targeted fishing exists for these fish.

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: Unknown

Fishery-specific effects on amount of large size target fish: Unknown

Fishery contribution to discards and offal production: Fishery discard rates during 2000-2004 have been 21-30 % for the shortraker/rougheye rockfish complex. The discard amount of species other than shortraker and rougheye rockfish in hauls targeting these fish is unknown.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: Unknown.

Fishery-specific effects on EFH non-living substrate: unknown, but the heavy-duty “rockhopper” trawl gear commonly used in the fishery can move around rocks and boulders on the bottom.

10.7.3 Data Gaps and Research Priorities

There is little information on larval, post-larval, or early stage juveniles of rougheye rockfish. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these.

10.8 Summary

We recommend the use of Model 3 from the above age-structured assessment. This model uses the new rougheye rockfish age error matrix, and the more accurate fishery catch proportion information. A

summary of the primary reference values (i.e. biomass levels, exploitation rates, author recommended ABCs and OFLs) for rougheye rockfish, along with projection values for next year are provided in the following table. Recommended values are in bold.

	2005	2006	2007*
Rougheye Rockfish Summary Table	2004 Model Projection ³ Not Updated	This year's projection Revised Model	
Tier 3a			
Total Biomass (3+)	45,070	37,449	-
Exploitable Biomass	29,732	24,537	-
B_{2006} (mt, female spawning)	12,311	9,976	10,165
$B_{100\%}$ (mt, female spawning)	27,280	20,997	-
$B_{40\%}$ (mt, female spawning)	10,912	8,399	8,399
$B_{35\%}$ (mt, female spawning)	9,548	7,349	-
M	0.034	0.035	0.035
$F_{50\%}$	0.027	0.027	0.027
F_{ABC} (maximum allowable = $F_{40\%}$)	0.039	0.039	0.039
F_{OFL} ($F_{35\%}$)	0.047	0.047	0.047
$ABC_{F50\%}$	806	683	670
$ABC_{F40\%}$ (mt, maximum allowable)	1,162	983	990
OFL (mt, $F_{35\%}$)	1,402	1,180	1,188

*The 2007 ABC and OFL were projected using an expected catch value of 288 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author's F method was used for this projection (Table 10-9) in response to management requests for a more accurate one-year projection.

In the future we may begin collecting ages from the longline survey and examine splitting the fishery data into trawl and longline fisheries. We may also examine the utility of applying depth stratification to the likelihood weighting on trawl and longline survey biomass estimates.

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³ 2004 Gulf of Alaska shortraker/rougheye and other slope rockfish, SAFE, Appendix B model output

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Table 10-1. Estimated catch history for GOA rougheye rockfish. Values from 1977-1992 are from Soh (1998). Values from 1993-2004 are from either the observer program or NPFMC, and NMFS regional office “blend estimates.” ABC and TAC were available for the shortraker/rougheye rockfish complex from 1991-2004. Separate ABCs were established for each species in 2005, and this value is provided for rougheye only.

Year	Catch (mt)		ABC	TAC
1977	1443			
1978	568			
1979	645			
1980	1353			
1981	719			
1982	569			
1983	628			
1984	760			
1985	130			
1986	438			
1987	525			
1988	1621			
1989	2185			
1990	2418			
1991	350		2,000	2,000
1992	1127		1,960	1,960
	<u>Observer Estimates</u>	<u>Blend estimates</u>	<u>Rougheye Only</u>	<u>Rougheye Only</u>
1993	583	830	1,960	1,764
1994	579	788	1,960	1,960
1995	704	968	1,910	1,910
1996	558	714	1,910	1,910
1997	545	692	1,590	1,590
1998	665	747	1,590	1,590
1999	320	564	1,590	1,590
2000	530	750	1,730	1,730
2001	591	850	1,730	1,730
2002	273	569	1,620	1,620
2003	394	603	1,620	1,620
2004	301	429	1,318	1,318
2005	289	289	1,007	1,007

Table 10-2. Fishery size compositions for GOA rougheye rockfish and sample size by year and pooled pairs of adjacent lengths. No data are available for 1989, and 1993-2002.

<u>Length (cm)</u>	<u>Year</u>							
	<u>1987</u>	<u>1988</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>2003</u>	<u>2004</u>	<u>2005</u>
21	0.008	0.000	0.010	0.000	0.002	0.000	0.001	0.000
23	0.010	0.000	0.008	0.000	0.005	0.000	0.000	0.001
25	0.014	0.001	0.010	0.001	0.008	0.000	0.002	0.002
27	0.008	0.002	0.011	0.002	0.012	0.001	0.001	0.002
29	0.020	0.002	0.010	0.006	0.017	0.003	0.007	0.005
31	0.012	0.003	0.011	0.002	0.025	0.003	0.006	0.008
33	0.018	0.012	0.008	0.012	0.031	0.007	0.010	0.007
35	0.010	0.012	0.012	0.010	0.046	0.010	0.010	0.011
37	0.043	0.012	0.017	0.015	0.058	0.015	0.022	0.030
39	0.043	0.023	0.031	0.032	0.088	0.039	0.023	0.032
41	0.073	0.089	0.076	0.053	0.125	0.056	0.040	0.042
43	0.075	0.189	0.164	0.145	0.144	0.105	0.062	0.070
45	0.114	0.237	0.210	0.236	0.169	0.142	0.115	0.116
47	0.159	0.185	0.163	0.202	0.110	0.190	0.161	0.153
49	0.175	0.088	0.086	0.149	0.068	0.172	0.164	0.149
51	0.114	0.049	0.035	0.053	0.031	0.111	0.144	0.129
53	0.065	0.021	0.019	0.020	0.018	0.071	0.104	0.092
55	0.029	0.021	0.016	0.013	0.017	0.031	0.061	0.056
57	0.006	0.026	0.011	0.009	0.010	0.020	0.029	0.029
59	0.000	0.019	0.010	0.007	0.009	0.008	0.018	0.023
60+	0.002	0.009	0.083	0.034	0.007	0.015	0.022	0.044
Sample size	491	941	12,419	1279	1118	2333	2133	1332

Table 10-3. GOA rougheye rockfish biomass estimates from NMFS triennial/biennial trawl surveys in the Gulf of Alaska. S.E. = Standard error. We exclude the 2001 survey because no sampling was performed in the Eastern Gulf. LCI and UCI are the lower and upper 95% confidence intervals respectively.

<u>Year</u>	<u>1984</u>	<u>1987</u>	<u>1990</u>	<u>1993</u>	<u>1996</u>	<u>1999</u>	<u>2003</u>	<u>2005</u>
Biomass	45,091	43,681	44,837	61,863	45,913	39,560	43,202	47,862
S.E.	7,313	4,897	9,296	14,415	7,432	5,793	6,724	8,618
LCI	30,758	34,083	26,616	33,610	31,346	28,206	30,024	30,970
UCI	59,425	53,278	63,057	90,115	60,481	50,913	56,380	64,754

Table 10-4. GOA Rougheye rockfish trawl survey age compositions extrapolated to population. Pooled age 25+ includes all fish 25 and older.

<u>Age (yr)</u>	<u>1990</u>	<u>1999</u>	<u>2003</u>
3	0.0011	0	0.0459
4	0.0025	0.0267	0.0181
5	0.0058	0.0532	0.0657
6	0.0105	0.0251	0.0457
7	0.0395	0.0325	0.0270
8	0.0503	0.0585	0.0544
9	0.1100	0.1371	0.0500
10	0.1684	0.0504	0.0229
11	0.0918	0.0432	0.0200
12	0.0231	0.0186	0.0370
13	0.0548	0.0431	0.0380
14	0.0876	0.0440	0.0419
15	0.0285	0.0448	0.0134
16	0.0132	0.0543	0.0303
17	0.0075	0.0462	0.0249
18	0.0036	0.0562	0.0166
19	0.0206	0.0297	0.0191
20	0.0073	0.0360	0.0458
21	0.0088	0.0187	0.0307
22	0.0074	0.0191	0.0388
23	0.0098	0.0174	0.0389
24	0.0211	0.0129	0.0241
25+	0.2267	0.1323	0.2508
Sample size	216	650	510

Table 10-5. NMFS trawl survey length compositions for GOA roughey rockfish. 1990, 1999, and 2003 not explicitly used in model because trawl survey ages were available for these years. 2001 is excluded because the Eastern Gulf was not sampled.

<u>Length (cm)</u>	<u>1984</u>	<u>1987</u>	<u>1990</u>	<u>1993</u>	<u>1996</u>	<u>1999</u>	<u>2001</u>	<u>2003</u>	<u>2005</u>
21	0.020	0.047	0.027	0.078	0.079	0.159	0.110	0.156	0.188
23	0.016	0.032	0.017	0.017	0.049	0.057	0.033	0.052	0.045
25	0.026	0.030	0.024	0.022	0.052	0.046	0.038	0.039	0.047
27	0.023	0.028	0.027	0.027	0.046	0.038	0.045	0.038	0.054
29	0.019	0.028	0.042	0.032	0.037	0.050	0.054	0.043	0.057
31	0.033	0.039	0.062	0.044	0.049	0.064	0.047	0.051	0.056
33	0.036	0.050	0.084	0.049	0.049	0.058	0.041	0.052	0.050
35	0.044	0.055	0.101	0.065	0.044	0.062	0.056	0.042	0.056
37	0.055	0.070	0.118	0.072	0.060	0.057	0.064	0.038	0.051
39	0.057	0.070	0.086	0.100	0.061	0.066	0.080	0.047	0.060
41	0.083	0.079	0.069	0.116	0.082	0.072	0.088	0.061	0.067
43	0.143	0.083	0.061	0.125	0.111	0.075	0.122	0.090	0.071
45	0.164	0.111	0.092	0.118	0.107	0.073	0.088	0.103	0.067
47	0.118	0.108	0.081	0.072	0.078	0.056	0.061	0.086	0.041
49	0.076	0.084	0.046	0.030	0.044	0.034	0.037	0.054	0.027
51	0.039	0.040	0.022	0.011	0.023	0.020	0.015	0.023	0.023
53	0.019	0.022	0.010	0.006	0.014	0.007	0.008	0.009	0.012
55	0.009	0.008	0.009	0.003	0.005	0.003	0.003	0.006	0.007
57	0.006	0.005	0.007	0.003	0.006	0.002	0.005	0.003	0.006
59	0.004	0.003	0.005	0.003	0.002	0.002	0.002	0.002	0.004
60+	0.009	0.007	0.009	0.007	0.002	0.002	0.003	0.004	0.010
Sample size	5,205	4,511	3,522	5,818	4,427	7,602	2,191	3,030	4,092

Table 10-6. GOA roughey rockfish relative population weights estimated from annual Gulf of Alaska longline survey. S.E. = Standard Error. LCI and UCI are the lower and upper 95% confidence intervals respectively.

<u>Year</u>	<u>RPW</u>	<u>S.E.</u>	<u>LCI</u>	<u>UCI</u>
1990	26,202	5,240	15,931	36,473
1991	33,341	6,668	20,271	46,410
1992	25,534	5,107	15,525	35,544
1993	28,782	5,756	17,499	40,064
1994	28,622	5,724	17,402	39,842
1995	33,663	6,733	20,467	46,858
1996	32,002	6,400	19,457	44,547
1997	46,456	9,291	28,245	64,666
1998	32,247	6,449	19,606	44,888
1999	35,299	7,060	21,462	49,136
2000	49,935	9,987	30,361	69,510
2001	35,267	7,053	21,442	49,091
2002	33,582	6,716	20,418	46,747
2003	33,611	6,722	20,435	46,786
2004	31,270	6,254	19,012	43,527
2005	22,342	4,468	13,584	31,099

Table 10-7. Size compositions for GOA roughey rockfish from the annual longline survey. Ages are binned in adjacent pairs and pooled at 60 and greater cm.

<u>Length (cm)</u>	<u>1990</u>	<u>1991</u>	<u>1992</u>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2004</u>	<u>2005</u>
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
25	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.001
27	0.002	0.001	0.001	0.003	0.001	0.002	0.000	0.001	0.000	0.003	0.002	0.003	0.003	0.001	0.004	0.006
29	0.002	0.003	0.004	0.003	0.003	0.003	0.001	0.002	0.002	0.005	0.002	0.005	0.005	0.004	0.011	0.016
31	0.007	0.006	0.008	0.010	0.005	0.006	0.005	0.005	0.006	0.009	0.005	0.013	0.008	0.009	0.021	0.029
33	0.010	0.012	0.013	0.014	0.008	0.015	0.008	0.008	0.008	0.012	0.014	0.015	0.019	0.014	0.017	0.031
35	0.014	0.017	0.020	0.023	0.011	0.019	0.015	0.013	0.021	0.020	0.018	0.027	0.024	0.014	0.027	0.034
37	0.025	0.026	0.027	0.037	0.020	0.024	0.022	0.018	0.026	0.027	0.027	0.031	0.034	0.025	0.035	0.042
39	0.032	0.036	0.038	0.046	0.028	0.044	0.039	0.034	0.036	0.034	0.039	0.044	0.054	0.051	0.041	0.053
41	0.048	0.056	0.058	0.066	0.042	0.067	0.053	0.057	0.056	0.055	0.057	0.060	0.071	0.080	0.060	0.068
43	0.080	0.100	0.093	0.108	0.065	0.093	0.094	0.094	0.091	0.096	0.091	0.093	0.103	0.106	0.092	0.109
45	0.132	0.137	0.150	0.143	0.118	0.132	0.134	0.143	0.146	0.153	0.140	0.135	0.133	0.136	0.142	0.155
47	0.163	0.189	0.173	0.175	0.172	0.167	0.191	0.182	0.182	0.200	0.175	0.169	0.159	0.185	0.184	0.171
49	0.173	0.183	0.180	0.156	0.198	0.164	0.210	0.186	0.179	0.184	0.182	0.169	0.157	0.168	0.169	0.144
51	0.120	0.117	0.122	0.104	0.154	0.131	0.127	0.133	0.124	0.119	0.118	0.121	0.111	0.105	0.103	0.070
53	0.063	0.058	0.058	0.056	0.092	0.061	0.055	0.064	0.059	0.054	0.068	0.059	0.064	0.056	0.049	0.037
55	0.029	0.029	0.023	0.029	0.044	0.034	0.025	0.025	0.025	0.017	0.029	0.027	0.023	0.020	0.019	0.015
57	0.018	0.011	0.012	0.013	0.018	0.014	0.011	0.012	0.016	0.004	0.016	0.011	0.014	0.011	0.012	0.008
59	0.007	0.007	0.007	0.006	0.008	0.010	0.005	0.009	0.008	0.002	0.006	0.006	0.009	0.006	0.006	0.004
60	0.071	0.013	0.012	0.009	0.014	0.015	0.007	0.012	0.014	0.004	0.011	0.012	0.009	0.009	0.006	0.009
Sample size	5,748	7,328	6,032	4,523	7,170	5,025	5,288	5,417	4,139	5,498	6,593	3,929	4,202	3,866	4,266	3,388

Table 10-8. Likelihoods and MLE estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for GOA rougheye rockfish models.

	<i>Model 1</i>		<i>Model 2</i>		<i>Model 3</i>	
Likelihoods	Value	Weight	Value	Weight	Value	Weight
Catch	0.481	1	0.531	1	0.512	1
Trawl Biomass	1.654	1	1.570	1	1.703	1
Longline Biomass	6.933	1	7.101	1	7.280	1
Trawl Survey Ages	30.384	1	23.481	1	23.600	1
Trawl Fishery Sizes	39.254	1	39.544	1	39.476	1
Trawl Survey Sizes	42.115	1	43.189	1	42.859	1
Longline Survey Sizes	44.357	1	44.301	1	44.334	1
<i>Data-Likelihood</i>	165.179		159.718		159.764	
Penalties/Priors						
Recruit Deviations	6.331	1	4.827	1	4.589	1
Fishery Selectivity	1.203	1	1.147	1	1.147	1
Trawl Selectivity	0.833	1	0.751	1	0.711	1
Longline Selectivity	1.690	1	1.716	1	1.722	1
Fish-Sel Domeshape	0.002	1	0.002	1	0.002	1
Survey-Sel Domeshp	0.067	1	0.043	1	0.035	1
LL-Sel Domeshape	0.000	1	0.000	1	0.000	1
Average Selectivity	0.000	0	0.000	0	0.000	0
F Regularity	0.907	0.1	0.890	0.1	0.978	0.1
σ_r prior	2.242		2.538		2.588	
q -trawl	0.520		0.431		0.630	
q -longline	0.013		0.017		0.048	
M	0.978		1.043		1.082	
Total	14.786		13.406		13.532	
<i>Objective Fun. Total</i>	180.376		173.535		173.707	
Parameter Estimates	Value	σ	Value	σ	Value	σ
q -trawl	1.578	0.470	1.515	0.468	1.652	0.490
q -longline	1.175	0.396	1.202	0.396	1.363	0.454
M	0.035	0.003	0.035	0.003	0.035	0.003
σ_r	0.962	0.062	0.954	0.060	0.953	0.060
Log-mean-rec	0.114	0.320	0.129	0.312	0.032	0.312
$F_{40\%}$	0.039	0.008	0.039	0.008	0.039	0.008
Total Biomass (mt)	42,385	14,010	41,511	13,694	37,449	12,209
$B_{200\%}$ (mt)	11,220	3,997	10,992	3,865	9,976	3,466
$B_{100\%}$ (mt)	24,285		22,564		20,997	
$B_{40\%}$ (mt)	9,714		9,026		8,399	
$ABC_{F40\%}$ (mt)	1,135		1,086		983	
$F_{50\%}$	0.027	0.005	0.027	0.005	0.027	0.005
$ABC_{F50\%}$ (mt)	789		755		683	

Table 10-9. Set of projections of spawning biomass (SB) and yield for GOA roughey rockfish. Six harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see section 10.6.3. All units in mt. $B_{40\%} = 8,399$ mt, $B_{35\%} = 7,349$ mt, $F_{40\%} = 0.039$, and $F_{35\%} = 0.047$.

Year	Maximum permissible F	Author's F (pre-specified catch)*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
Spawning Biomass (mt)							
2005	9,770	9,770	9,770	9,770	9,770	9,770	9,770
2006	9,857	9,970	9,936	9,944	10,016	9,825	9,857
2007	9,760	10,028	10,027	10,053	10,302	9,653	9,760
2008	9,695	9,956	10,147	10,191	10,621	9,516	9,664
2009	9,591	9,843	10,220	10,281	10,893	9,345	9,486
2010	9,515	9,758	10,316	10,394	11,188	9,206	9,341
2011	9,478	9,711	10,446	10,541	11,519	9,110	9,239
2012	9,469	9,691	10,595	10,708	11,867	9,046	9,168
2013	9,530	9,741	10,809	10,938	12,280	9,055	9,170
2014	9,659	9,860	11,090	11,236	12,763	9,134	9,243
2015	10,021	10,216	11,639	11,805	13,563	9,434	9,540
2016	10,195	10,379	11,965	12,148	14,101	9,561	9,659
2017	10,352	10,525	12,278	12,479	14,636	9,667	9,758
2018	10,479	10,643	12,563	12,781	15,146	9,746	9,831
Fishing Mortality							
2005	0.012	0.012	0.012	0.012	0.012	0.012	0.012
2006	0.039	0.011	0.020	0.018	-	0.047	0.039
2007	0.039	0.039	0.020	0.018	-	0.047	0.039
2008	0.039	0.039	0.020	0.018	-	0.047	0.047
2009	0.039	0.039	0.020	0.018	-	0.047	0.047
2010	0.039	0.039	0.020	0.018	-	0.047	0.047
2011	0.039	0.039	0.020	0.018	-	0.047	0.047
2012	0.039	0.039	0.020	0.018	-	0.047	0.047
2013	0.039	0.039	0.020	0.018	-	0.047	0.047
2014	0.039	0.039	0.020	0.018	-	0.047	0.047
2015	0.039	0.039	0.020	0.018	-	0.047	0.047
2016	0.039	0.039	0.020	0.018	-	0.047	0.047
2017	0.039	0.039	0.020	0.018	-	0.047	0.047
2018	0.039	0.039	0.020	0.018	-	0.047	0.047
Yield (mt)							
2005	289	289	289	289	289	289	289
2006	983	983	496	450	-	1,180	983
2007	964	990	496	451	-	1,149	964
2008	946	970	495	451	-	1,118	1,135
2009	931	954	496	452	-	1,093	1,109
2010	935	957	506	462	-	1,092	1,107
2011	931	952	511	467	-	1,081	1,094
2012	921	940	513	469	-	1,062	1,075
2013	937	955	527	484	-	1,076	1,088
2014	973	991	553	507	-	1,114	1,126
2015	1,029	1,046	588	540	-	1,175	1,186
2016	1,140	1,156	652	599	-	1,302	1,313
2017	1,118	1,133	649	597	-	1,270	1,280
2018	1,098	1,112	646	594	-	1,240	1,249

*The 2007 ABC was projected using an expected catch value of 288 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. This is in response to management requests for a more accurate one-year projection.

Table 10-10. Allocation of ABC and OFL for 2006 GOA roughey rockfish.

Year	Weights	Western Gulf	Central Gulf	Eastern Gulf	Total
2001	4	16%	55%	28%	100%
2003	6	21%	57%	22%	100%
2005	9	8%	68%	24%	100%
Weighted Mean	19	14%	62%	24%	100%
Area Allocation		14%	62%	24%	100%
Area ABC (mt)		136	608	239	983
OFL (mt)					1,180

Table 10-11: Analysis of ecosystem considerations for GOA rougheye rockfish.

Ecosystem effects on GOA rougheye rockfish			
Indicator	Observation	Interpretation	Evaluation
<i>Prey availability or abundance trends</i>			
Phytoplankton and Zooplankton	Important for larval and post-larval survival but no information known	May help determine year class strength, no time series	Possible concern if some information available
<i>Predator population trends</i>			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, arrowtooth, lingcod)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
<i>Changes in habitat quality</i>			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment
GOA rougheye rockfish fishery effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
<i>Fishery contribution to bycatch</i>			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
<i>Fishery concentration in space and time</i>	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several month starting 2006
<i>Fishery effects on amount of large size target fish</i>	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
<i>Fishery contribution to discards and offal production</i>	Decreasing	Improving, but data limited	Possible concern with non-target rockfish
<i>Fishery effects on age-at-maturity and fecundity</i>	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies being initiated in 2005

Table 10-12: Bycatch (kg) and bycatch rates during 1997 - 2005 of living substrates in the Gulf of Alaska for combined rockfish fisheries, all gears. Source: Alaska Regional Office Data prepared by Gaichas and Ackley, unpublished data. Rockfish catch for 2005 is an estimate.

<u>Non-target species</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>2004</u>	<u>2005</u>	<u>Average</u>
	<u>Bycatch (kg)</u>									
Sea Pens/Whips	0	0	23	12	30	18	0	2	43	14
Sponges	1,504	643	5,393	1,482	1,887	1,951	3,815	1,140	1,130	2,105
Anemones	459	15	673	1,438	255	335	3,304	2,940	296	1,079
Tunicates	14	45	6	481	8	38	2	130	0	80
Echinoderms	2,023	532	2,016	773	2,952	683	3,467	2,103	1,514	1,785
Coral	1,636	330	766	10,005	4,317	15,143	1,904	65	6,125	4,477
Rockfish Catch (tons)	13,083	13,592	18,333	15,947	15,672	16,977	20,144	20,012	20,000	17,084
	<u>Bycatch rate (kg/mt target)</u>									
Sea Pens/Whips	0.000	0.000	0.001	0.001	0.002	0.001	0.000	0.000	0.002	0.001
Sponges	0.115	0.047	0.294	0.093	0.120	0.115	0.189	0.057	0.057	0.121
Anemones	0.035	0.001	0.037	0.090	0.016	0.020	0.164	0.147	0.015	0.058
Tunicates	0.001	0.003	0.000	0.030	0.001	0.002	0.000	0.006	0.000	0.005
Echinoderms	0.155	0.039	0.110	0.049	0.188	0.040	0.172	0.105	0.076	0.104
Coral	0.125	0.024	0.042	0.627	0.276	0.892	0.095	0.003	0.306	0.266

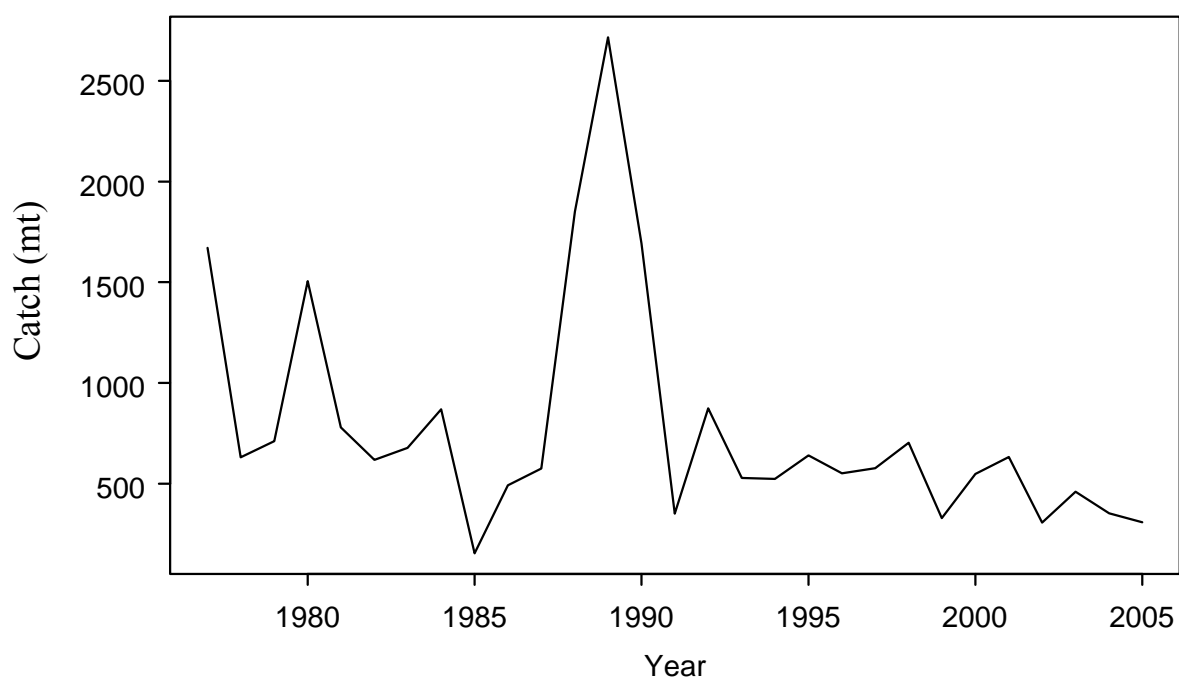


Figure 10-1. Estimated commercial catches for Gulf of Alaska rougheye rockfish using data from Soh (1998) and NMFS Alaska Regional Office. Observer proportions used to determine proportion of rougheye catch from 1993-2004. Data used in Model 3.

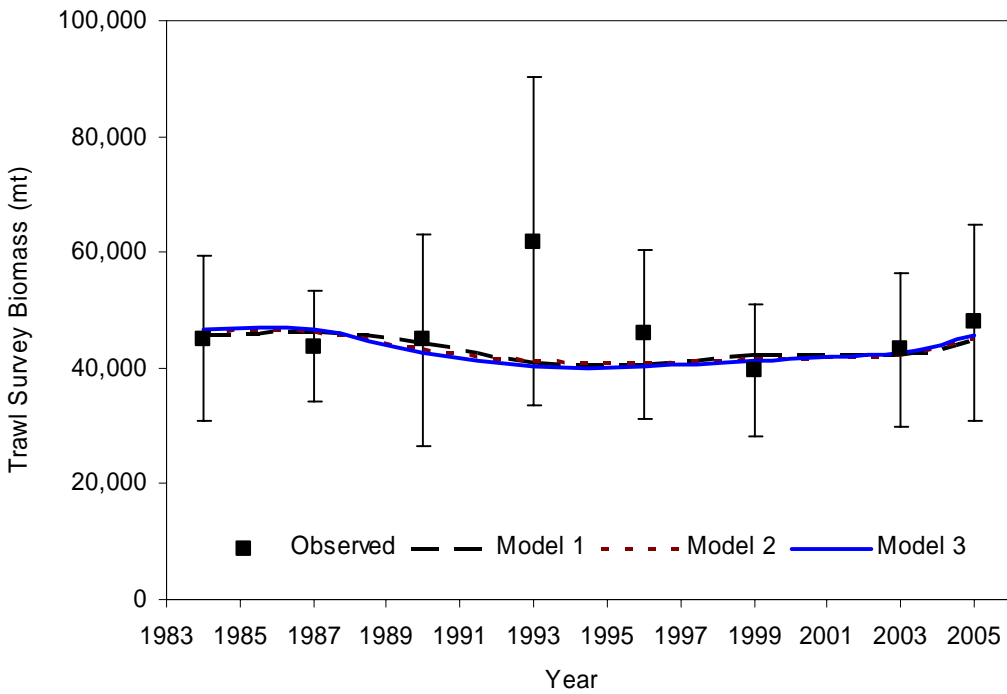


Figure 10-2. Observed and predicted GOA rougheye rockfish trawl survey biomass. Observed biomass = squares with 95% CIs of sampling error, predicted biomass Model 1 = large dash, Model 2 = short dash, Model 3 =solid line.

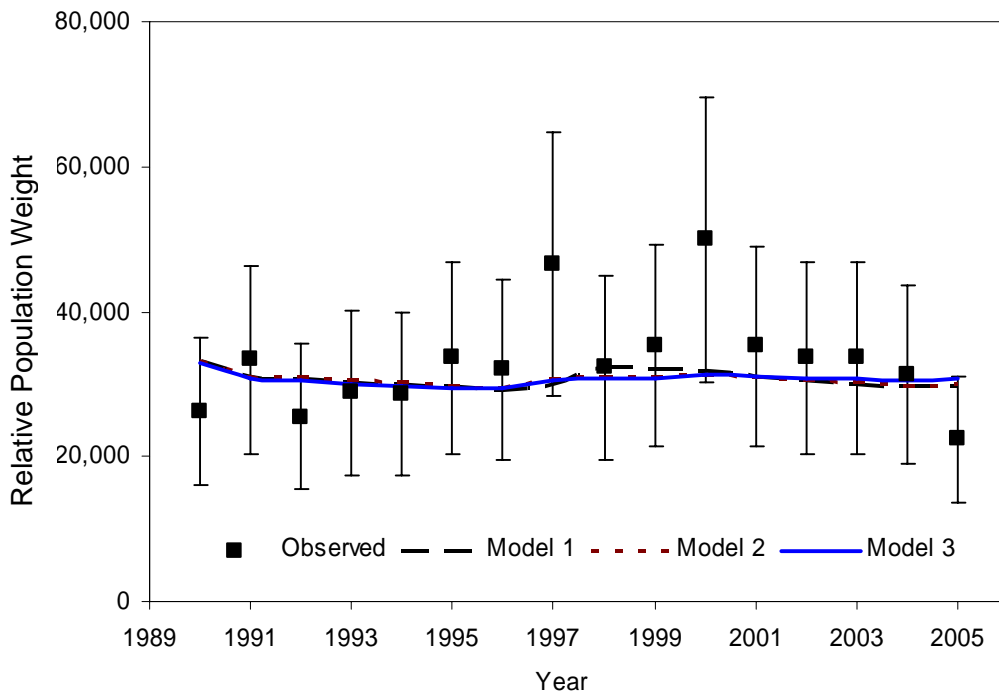


Figure 10-3. Observed and predicted GOA rougheye rockfish longline survey relative population weight (RPW). Observed biomass = squares with 95% CIs of sampling error, predicted biomass Model 1 = large dash, Model 2 = short dash, Model 3 =solid line.

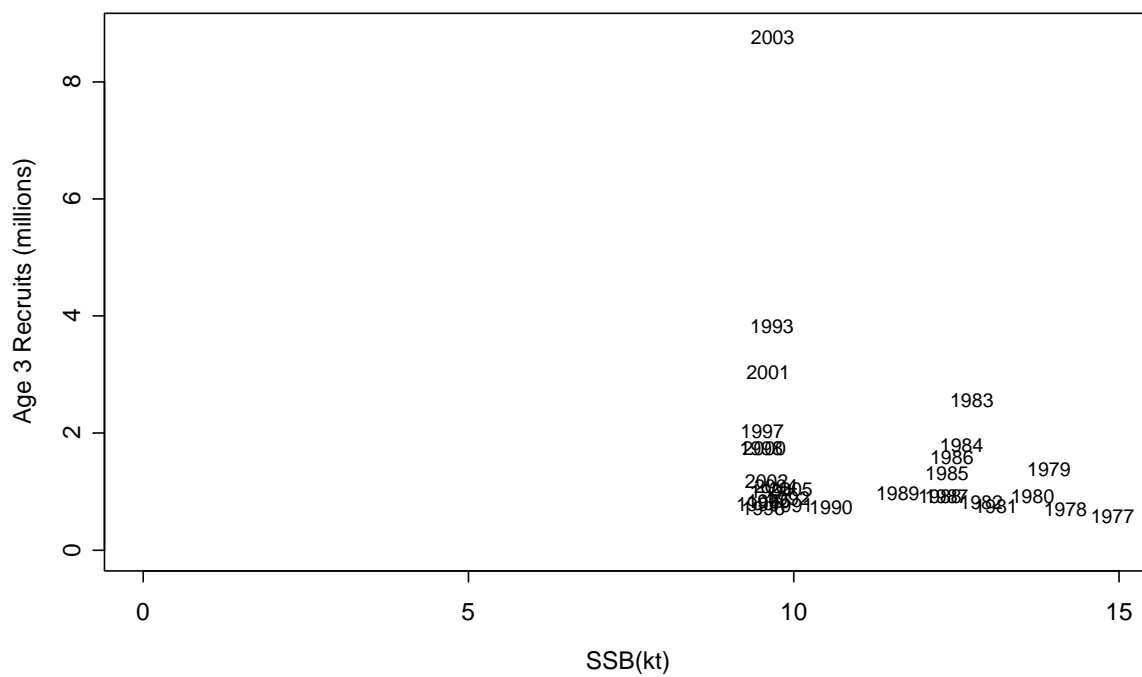


Figure 10-4. Scatterplot of spawner-recruit data for GOA rougheye rockfish estimated from Model 3. Label is year class of age 3 recruits. SSB = Spawning stock biomass in kilotons.

Proportion

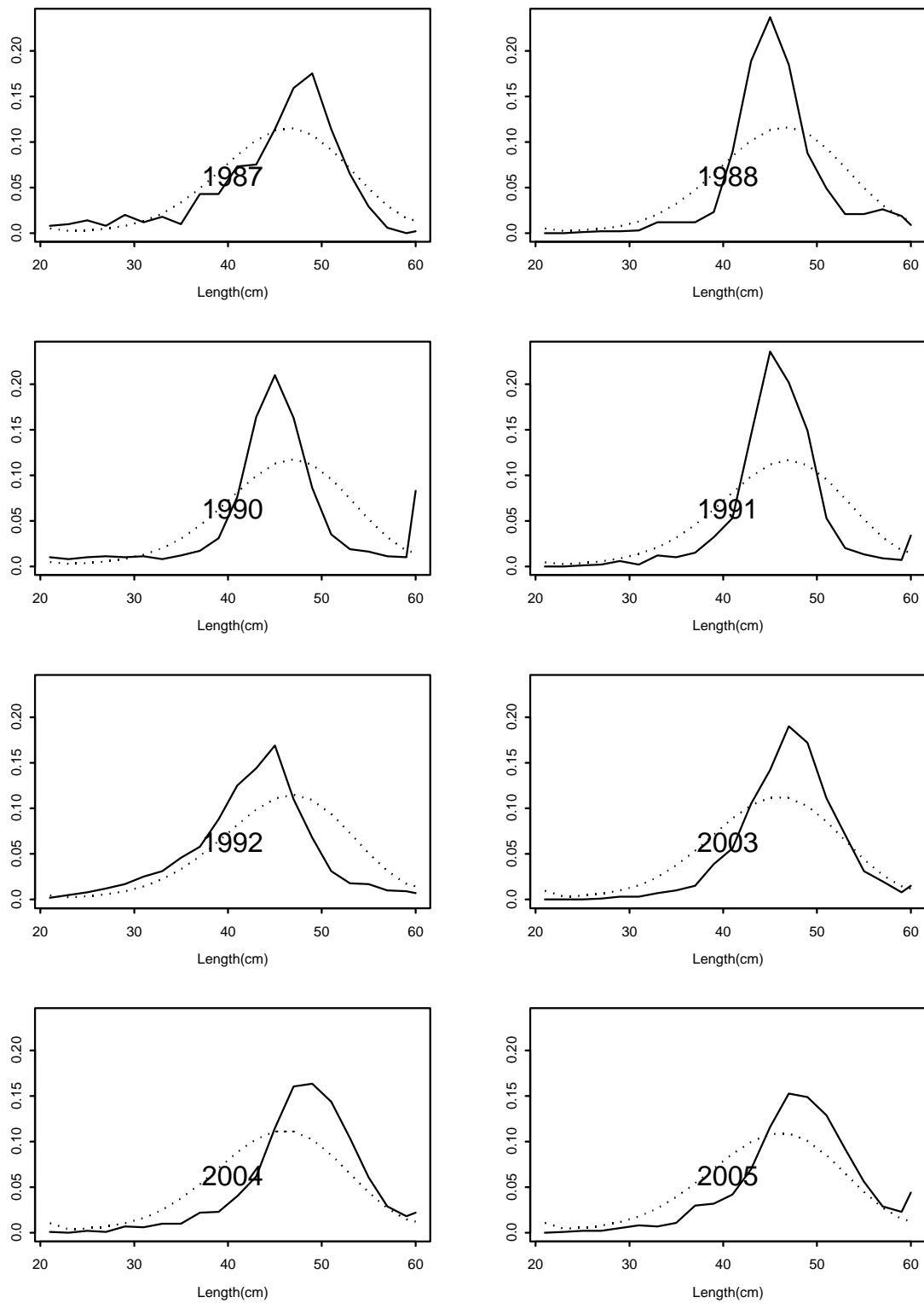


Figure 10-5. Trawl fishery length compositions for GOA roughey rockfish. Observed=solid line, predicted for Model 3=dotted line.

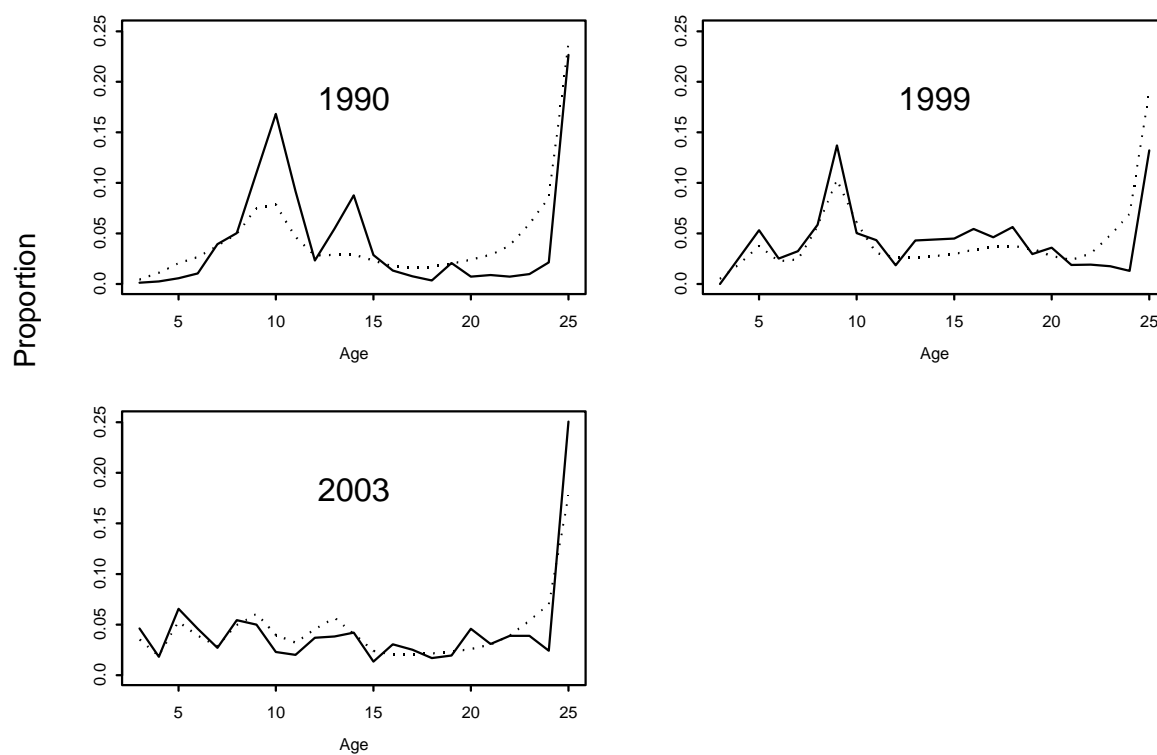


Figure 10-6. Trawl survey age composition by year for GOA roughey rockfish. Observed=solid line, predicted for Model 3=dotted line.

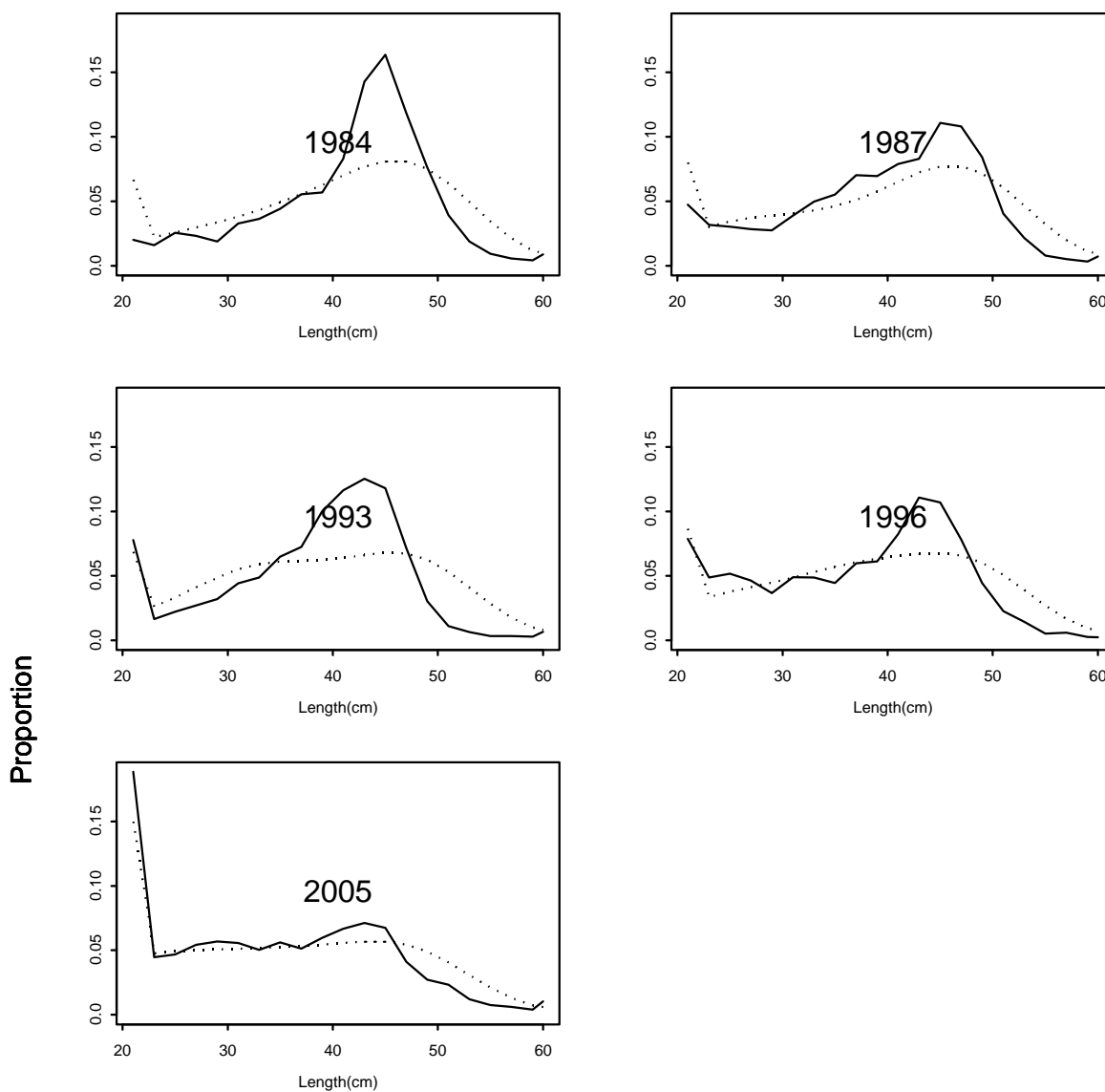


Figure 10-7. Trawl survey length composition by year for GOA roughey rockfish. Observed=solid line, predicted for Model 3=dotted line. Sizes distributions for 1990, 1999, and 2003 are not used in the model because survey ages for these years were available. Size distributions for 2001 are not used in the model because the survey did not sample the Eastern Gulf of Alaska.

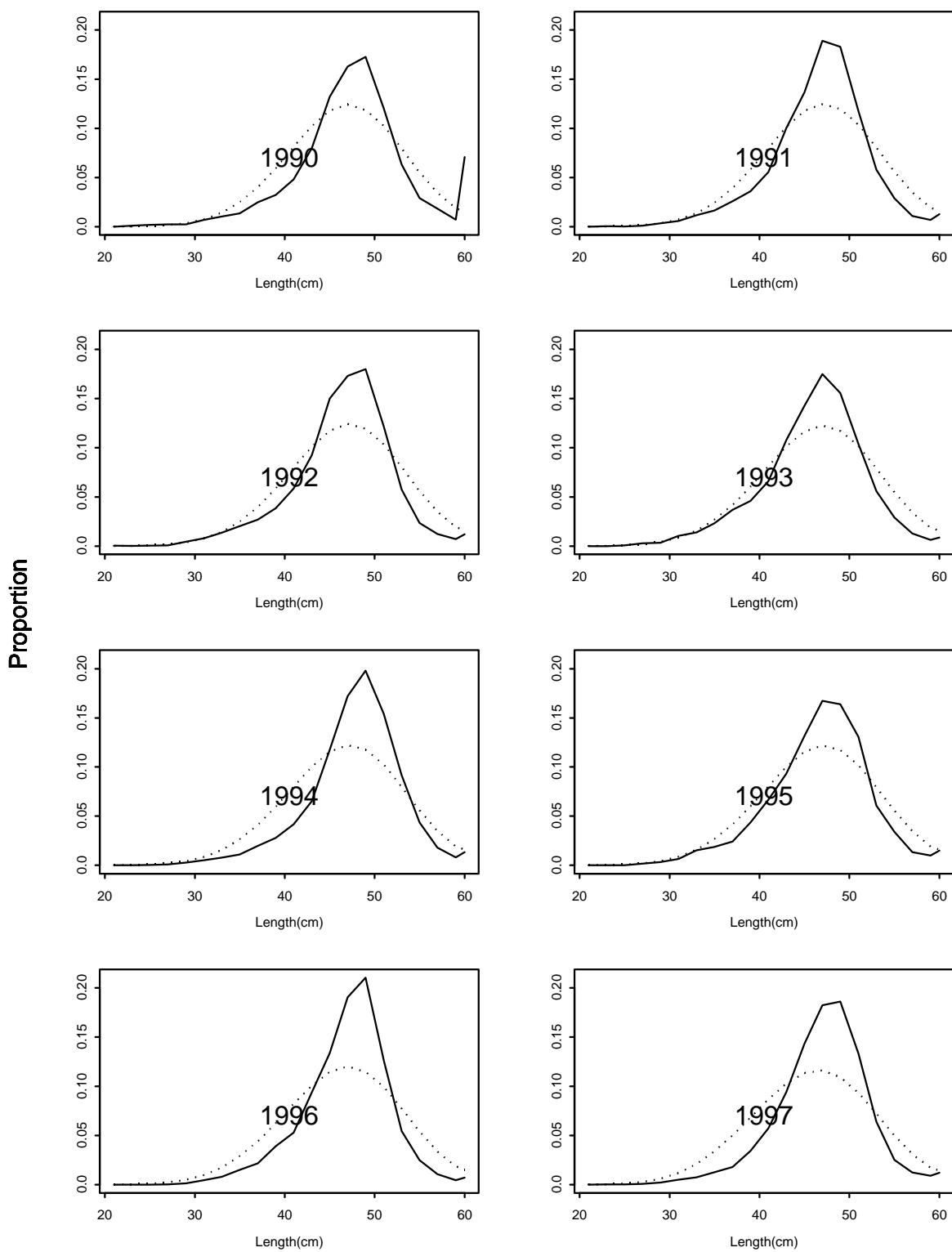


Figure 10-8. Longline survey length composition by year for GOA roughey rockfish. Observed=solid line, predicted for Model 3=dotted line.

Proportion

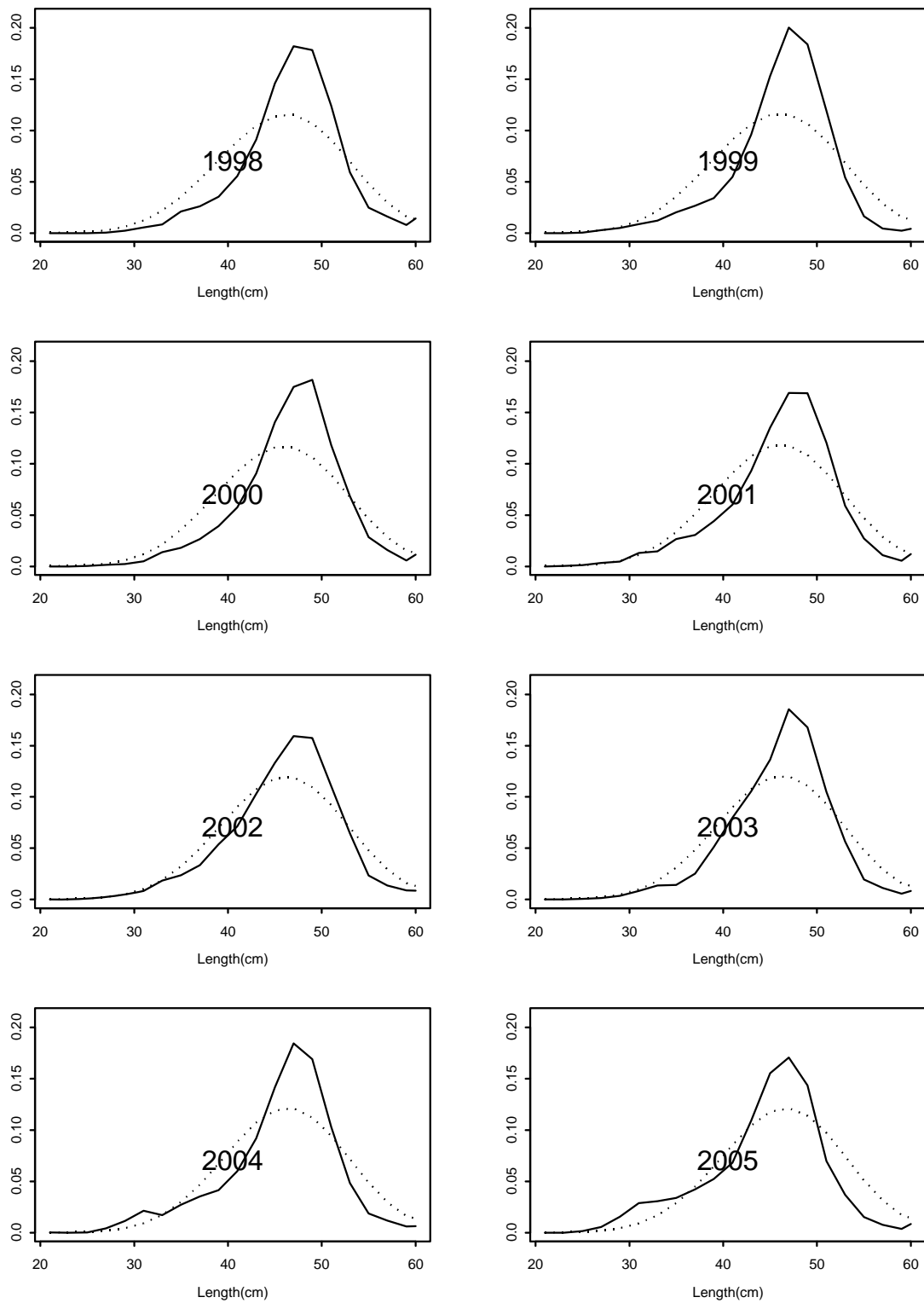


Figure 10-8 (continued). Longline survey length composition for GOA roughey rockfish. Observed=solid line, predicted for Model 3=dotted line.



Figure 10-9. Time series of estimated fully selected fishing mortality for GOA roughey rockfish from Model 3.

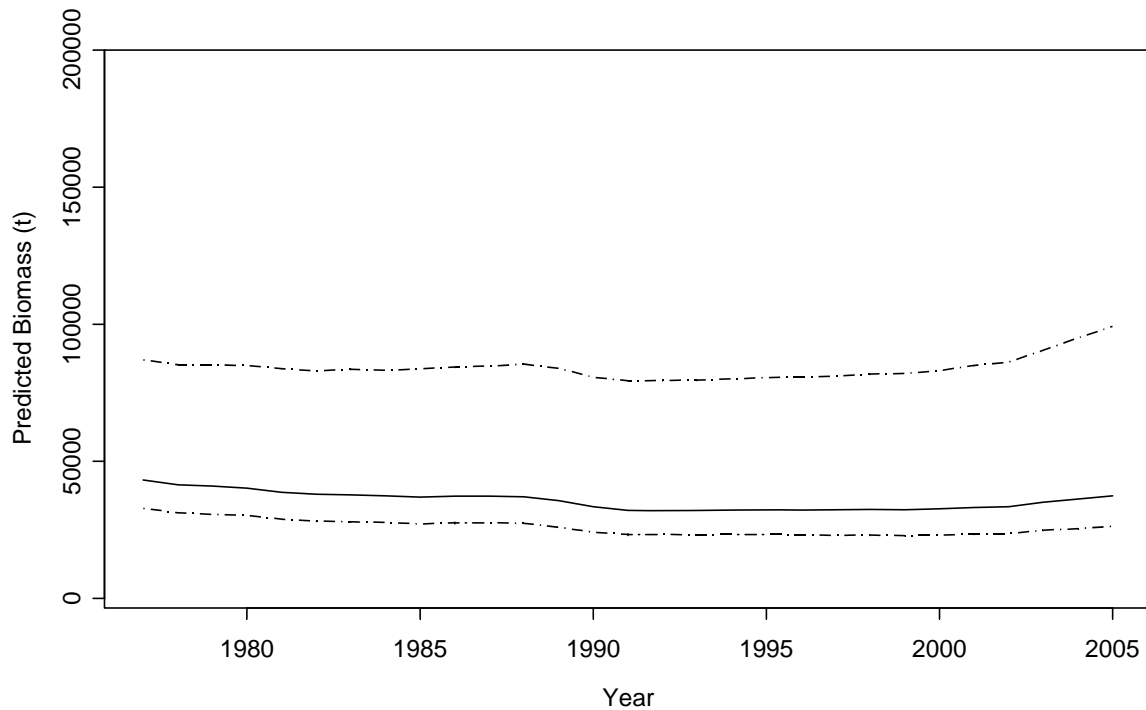


Figure 10-10. Time series of predicted total biomass for GOA roughey rockfish for Model 3. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

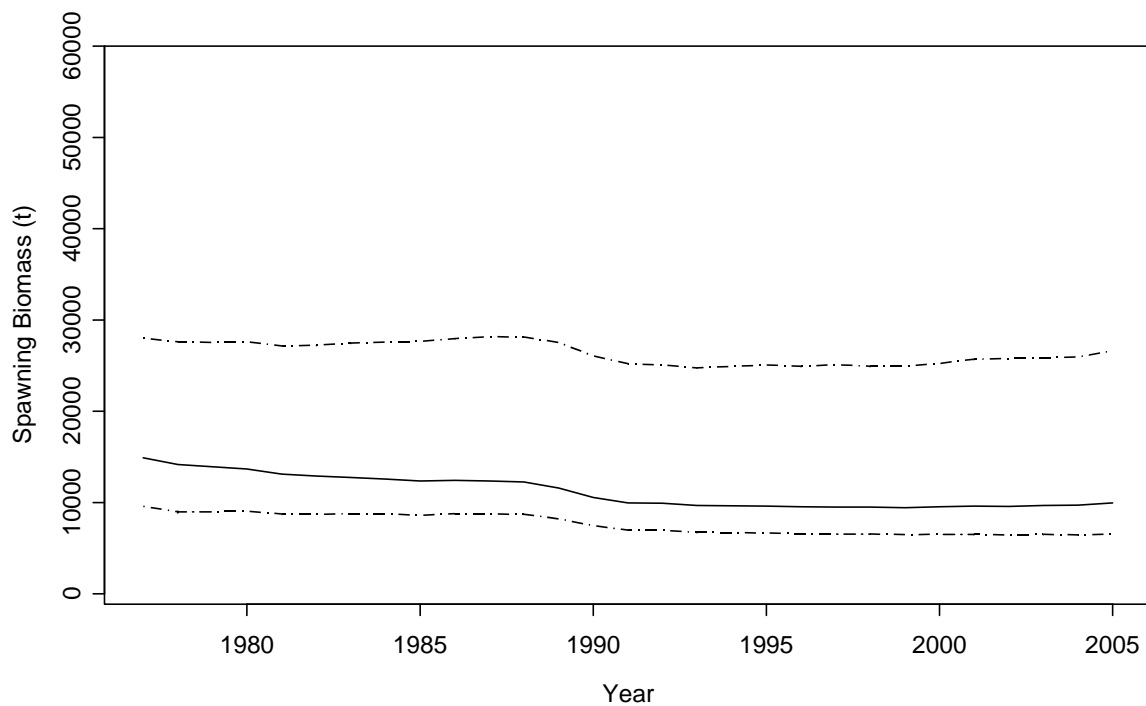


Figure 10-11. Time series of predicted spawning biomass of GOA roughey rockfish for Model 3. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

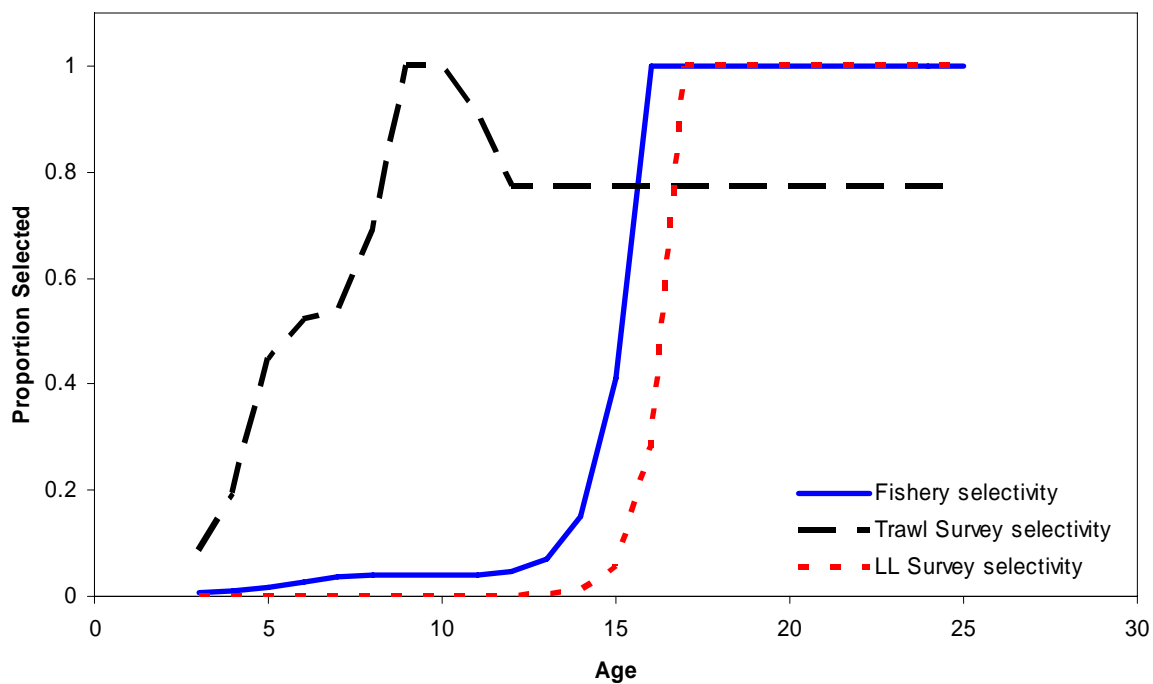


Figure 10-12. Estimated selectivity curves for Model 3 of GOA rougheye rockfish. Dashed line=Trawl survey selectivity, dotted line=Longline survey selectivity, Solid line=Combined fishery selectivity.

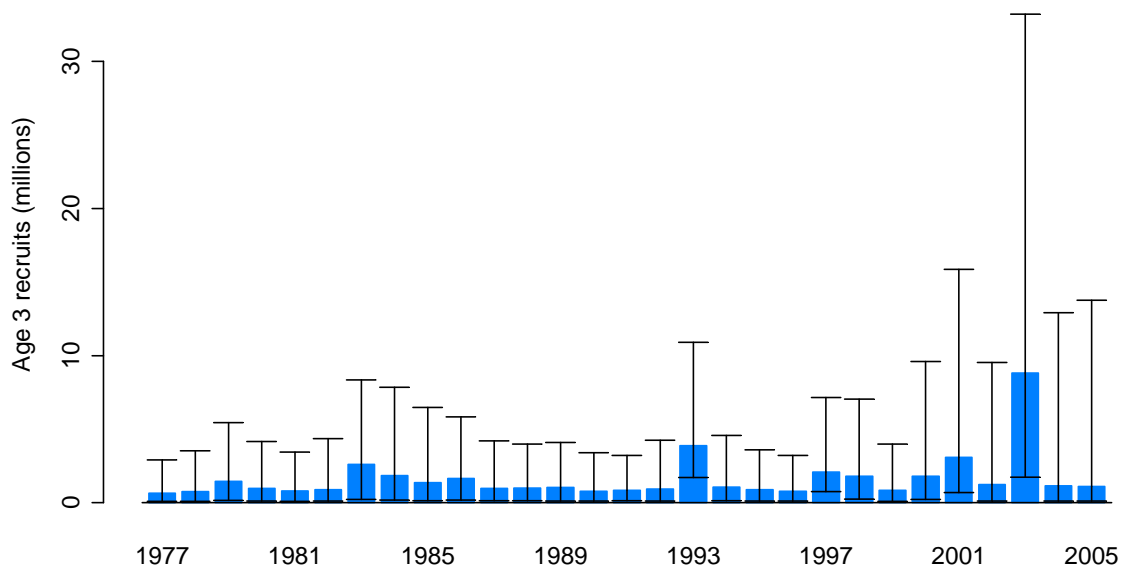


Figure 10-13. Estimated recruitments (age 3) for GOA rougheye rockfish from Model 3.

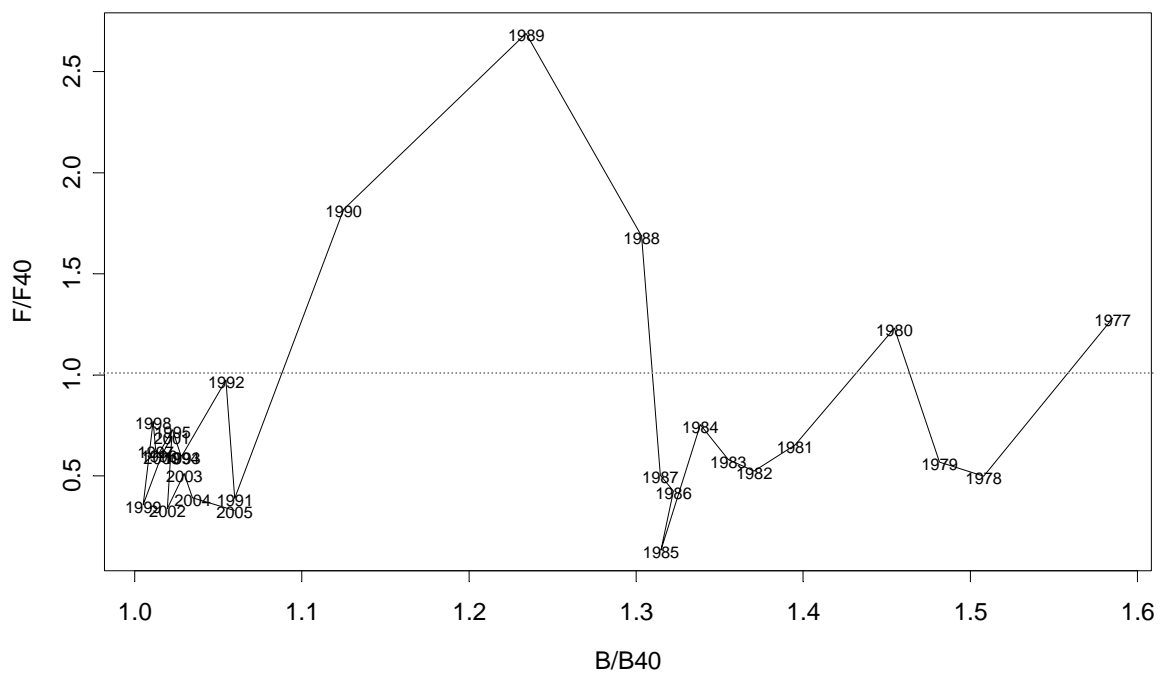


Figure 10-14. Time series of estimated fishing mortality over $F_{40\%}$ versus estimated spawning biomass over $B_{40\%}$ for GOA rougheye rockfish for Model 3.